IEEE Standards

IEEE Std C57.12.59-2001

C57.12.59™

IEEE Guide for Dry-Type Transformer Through-Fault Current Duration

IEEE Power Engineering Society

Sponsored by the
Transformers Committee

Published by
The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

10 January 2002

Print: SH94979
PDF: SS94979

Recognized as an
American National Standard (ANSI)

IEEE Std C57.12.59-2001

IEEE Guide for Dry-Type Transformer Through-Fault Current Duration

Sponsor

Transformers Committee
of the
IEEE Power Engineering Society

Approved 30 April 2002

American National Standards Institute

Approved 6 December 2001

IEEE-SA Standards Board

Abstract: This guide sets forth recommendations believed essential for the application of overcurrent protective devices that limit the exposure time of dry-type transformers to short-circuit currents. This guide is not intended to imply overload capability.
Keywords: dry-type transformers, normal base current, overcurrent protective devices, transformer short-circuit impedance

---

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

Print: ISBN 0-7381-3104-0 SH94979
PDF: ISBN 0-7381-3105-9 SS94979

Introduction

(This introduction is not a part of IEEE Std C57.12.59-2001, IEEE Guide for Dry-Type Transformer Through-Fault Current Duration.)

This guide provides recommendations for the application of overcurrent protection devices to limit the exposure time of dry-type transformers to short circuits. It must not be confused with IEEE Std C57.109-1993, IEEE Guide for Liquid-Immersed Transformer Through-Fault Current Duration, which applies only to liquid-immersed transformers.

Dry-type transformers differ significantly from liquid-immersed types in several respects:

a) There are five different temperature ratings for dry-type transformers: 75 °C, 90 °C, 115 °C, 130 °C, and 150 °C; whereas there is only one temperature rating for liquid-immersed transformers: 65 °C.

b) There are significant variations in dry-type winding constructions, including conventional varnish impregnated layered windings, vertically stacked varnish-impregnated disk windings, solid-cast resin windings, and combinations thereof, all of which have different transient heating characteristics during time intervals greater than about 100 s.

c) The transient heating of liquid-immersed transformer windings are considerably buffered by the insulating medium in which they are immersed, providing a relatively long thermal time constant as compared to dry-type transformers.

Because of the foregoing, the through-fault protection curves for dry-type transformers are limited to overload time intervals of 100 s or less. No one curve for longer time intervals would characterize the thermal performance of all the different dry-type transformer constructions and temperature ratings. Moreover, such curves are not known or, at least, not available. Consequently, the curves in this guide pertain to the temperature rise of the windings during time intervals less than 100 s, wherein nearly all the heat generated is stored in the conductors. For longer time intervals, it is recommended that reference be made to IEEE Std C57.96-1999, IEEE Guide for Loading Dry-Type Distribution and Power Transformers.

As short-circuit time intervals become progressively less than 100 s, mechanical considerations become more important than thermal characteristics.

Short-circuit performance characteristics are contained in IEEE Std C57.12.01-1998, IEEE Standard General Requirements for Dry-Type Distribution and Power Transformers Including Those With Solid-Cast and/or Resin-Encapsulated Windings. This guide supplements that information, but in no way supersedes it.

Participants

At the time this guide was completed, the Working Group for Dry-Type Transformer Through-Fault Current Duration had the following membership:

Paulette A. Payne, *Chair*

Derek Foster	Philip J. Hopkinson	Charles W. Johnson, Jr.
Michael E. Haas	Rush Horton	Gene Morehart
N. Wayne Hansen		Bipin K. Patel

The following members of the balloting committee voted on this standard. Balloters may have voted for approval, disapproval, or abstention.

S. H. Aguirre
Jim Antweiler
Edward A. Bertolini
Thomas E. Blackburn, III
Alain Bolliger
Simon R. Chano
Peter W. Clarke
Guru Dutt Dhingra
Dieter Dohnal
J. C. Duart
George Gela
Randall C. Groves
Michael E. Haas
Robert H. Hartgrove
James D. Huddleston, III
Charles W. Johnson, Jr.
Anthony J. Jonnatti
John G. Lackey
Stephen R. Lambert
Donald L. Lowe
Allan Ludbrook
Don MacMillan
William A. Maguire
K. T. Massouda
John W. Matthews
Nigel P. McQuin
Joe Melanson
Gary L. Michel
Daniel H. Mulkey
Arthur S. Neubauer
Klaus Papp
Bipin K. Patel
Dhiru S. Patel
Wesley F. Patterson
Paulette A. Payne
Carlos O. Peixoto
Paul Pillitteri
Tom A. Prevost
Madan Rana
Radhakrishna V Rebbapragada
John R. Rossetti
Wes W. Schwartz
Pat Scully
Hyeong Jin Sim
James E. Smith
Ronald J. Stahara
Frank Stevens
Ron W. Stoner
John C. Sullivan
Subhash C Tuli
Gerald L. Vaughn
James W. Wilson
William G. Wimmer

When the IEEE-SA Standards Board approved this standard on 6 December 2001, it had the following membership:

Donald N. Heirman, *Chair*
James T. Carlo, *Vice Chair*
Judith Gorman, *Secretary*

Satish K. Aggarwal
Mark D. Bowman
Gary R. Engmann
Harold E. Epstein
H. Landis Floyd
Jay Forster*
Howard M. Frazier
Ruben D. Garzon
James H. Gurney
Richard J. Holleman
Lowell G. Johnson
Robert J. Kennelly
Joseph L. Koepfinger*
Peter H. Lips
L. Bruce McClung
Daleep C. Mohla
James W. Moore
Robert F. Munzner
Ronald C. Petersen
Gerald H. Peterson
John B. Posey
Gary S. Robinson
Akio Tojo
Donald W. Zipse

*Member Emeritus

Also included is the following nonvoting IEEE-SA Standards Board liaison:

Alan Cookson, *NIST Representative*
Donald R. Volzka, *TAB Representative*

Noelle D. Humenick
IEEE Standards Project Editor

Contents

IEEE Guide for Dry-Type Transformer Through-Fault Current Duration

1. Overview

1.1 Scope

This guide applies to dry-type transformers designated as Category I and Category II in IEEE Std C57.12.01-1998.[1] Category III transformers have not been included since these are not commonly manufactured and may require special consideration depending on the manufacturer's recommendations.

1.2 Purpose

Protective devices, such as relays and fuses, have well-defined operating characteristics that relate fault magnitude to clearing time. It is desirable that these characteristic curves be coordinated with comparable curves applicable to dry-type transformers that relate duration and fault magnitude to withstand capability.

This guide sets forth recommendations believed essential for the application of overcurrent protective devices that limit the exposure time of dry-type transformers to short-circuit currents. This guide is not intended to imply overload capability.

1.3 General

The magnitude and duration of fault currents are of utmost importance in establishing a coordinated protection practice for transformers, as both mechanical and thermal effects of fault currents must be considered. For fault-current magnitudes near the maximum short-circuit current rating of the transformer, mechanical effects are more significant than thermal effects. The maximum symmetrical short-circuit current should not exceed 25 times normal base current in accordance with IEEE Std C57.12.01-1998. At lower fault-current magnitudes approaching the overload range, mechanical effects are less important unless the frequency and duration of fault occurrence is high enough to promote mechanical degradation. The point of transition between mechanical concern and thermal concern cannot be precisely defined; mechanical effects tend to have a more prominent role in larger kVA ratings because the mechanical forces are greater.

[1]Information on references can be found in Clause 2.

2. References

This guide is to be used in conjunction with the following publications. If the following publications are superseded by an approved revision, the revision shall apply.

IEEE C37.91-2000, IEEE Guide for Protective Relay Applications to Power Transformers.[2]

IEEE C57.12.01-1998, IEEE Standard General Requirements for Dry-Type Distribution and Power Transformers Including Those with Solid-Cast and/or Resin-Encapsulated Windings.

IEEE C57.96-1999, IEEE Guide for Loading Dry-Type Distribution and Power Transformers.

3. Definitions

For the purposes of this guide, the following terms and definitions apply. *The Authoritative Dictionary of IEEE Standards Terms* [B1][3] should be referenced for terms not defined in this clause.

3.1 normal base current: Rated current of a transformer corresponding to its rated voltage and rated base kVA.

3.2 transformer short-circuit impedance: 1.) For Category I transformers, the transformer expressed in percent of rated voltage and rated base kVA of the transformer. 2.) For Category II transformers, the sum of transformer impedance and system short-circuit impedance at the transformer location, expressed in percent of rated voltage and rated base kVA of the transformer.

4. Transformer coordination

For the purposes of coordination of overcurrent protective devices, with transformer short-circuit withstand capability, Figure 1 and Figure 2 are presented as protection curves for Category I and Category II transformers as defined in IEEE Std C57.12.01-1998 and adopted in Table 1.

For Category I, a single curve applies that reflects both thermal and mechanical damage considerations.

For Category II, two curves apply, one of which reflects both thermal and mechanical damage considerations, while the other reflects primarily thermal damage considerations only. On curves that have both a solid and a dotted portion, the solid portion represents a total fault duration beyond which thermal damage to insulation adjacent to current-carrying conductors and anneal-softening of aluminum may occur, while the dotted portion represents a total fault duration beyond which cumulative mechanical damage may occur. The increasing significance of mechanical effects for higher kVA transformers is reflected in these curves. The frequency of faults varies with different transformer applications. Applications characterizing frequent and infrequent faults are presented in the annex of IEEE Std C37.91-2000.

The short-time thermal load capability of dry type transformers is summarized in Table 2.

The validity of these damage-limit curves cannot be demonstrated by test, since the effects are progressive over the transformer lifetime. The curves are based principally on informed engineering judgement and favorable historical field experience.

[2]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (http://standards.ieee.org/).
[3]The numbers in brackets correspond to those of the bibliography in Annex A.

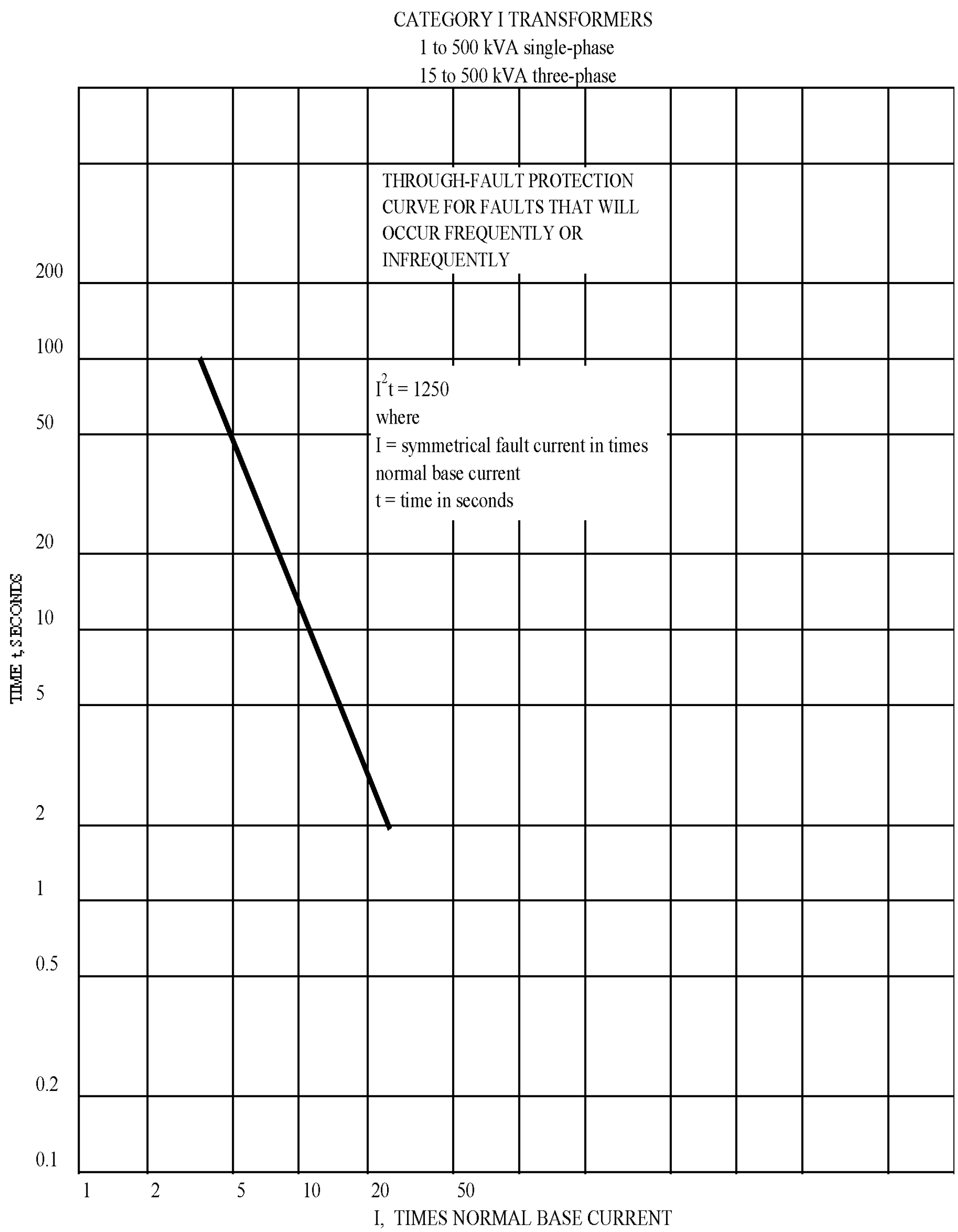

Figure 1—Category I transformers

The per-unit short-circuit currents shown in Figure 1 and Figure 2 are the balanced transformer winding currents. The line currents that relate to these winding currents depend upon the transformer connection and the type of fault present. Application engineers must relate the winding currents to the currents seen by the protective devices in order to protect the transformer within its capability.

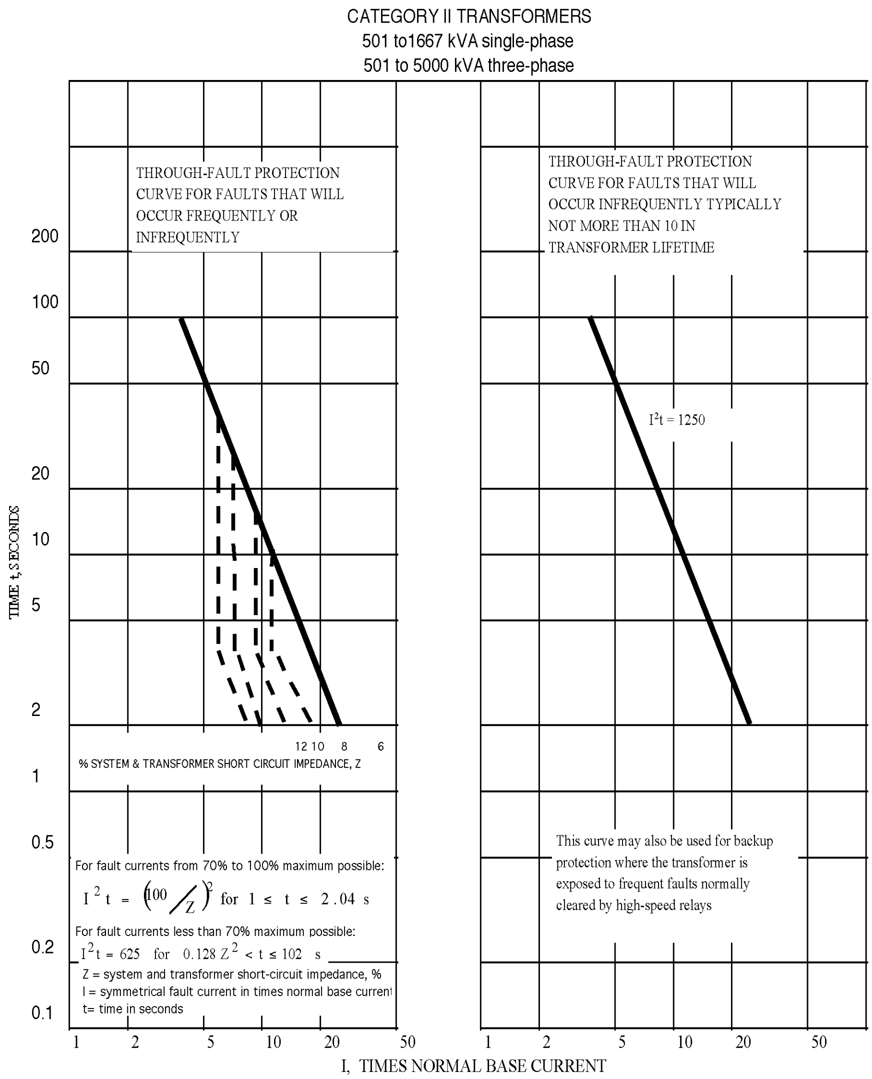

Figure 2—Category II transformers

4.1 Category I transformers

The recommended duration limit is based on the curve in Figure 1. The curve reflects both thermal and mechanical damage considerations and should be applied as a protection curve for faults that will occur frequently or infrequently.

4.2 Category II transformers

The recommended duration limits depend upon fault frequency and are based upon the curves in Figure 2. Fault frequency refers to the number of faults with magnitudes greater than 70% of maximum as limited by system and transformer short-circuit impedance.

4.2.1 Faults that occur frequently

The left-hand curve, reflecting both thermal and mechanical damage considerations, should be applied as a protection curve for faults that will occur frequently (typically more than 10 in a transformer lifetime). It is dependent upon the short-circuit impedance of the transformer for fault currents above 70% of maximum possible and is keyed to the I^2t of the worst-case mechanical duty (maximum fault current for 2 s).

4.2.2 Faults that occur infrequently

The right-hand curve reflects primarily thermal damage considerations. It is not dependent upon short-circuit impedance of the transformer and may be applied as a protection curve for faults which will occur only infrequently (typically not more than 10 in a transformer lifetime). This curve may also be used for backup protection where the transformer is exposed to frequent faults normally cleared by high-speed relaying.

Table 1—Transformer categories

Category[a]	Single-phase (kVA)[b]	Three-phase (kVA)[b]	Reference protection curves
I	1–500	15–500	Figure 1
II	501–1667	501–5000	Figure 2

[a]Category I includes autotransformers of 500 kVA or less (equivalent two-winding) even though nameplate kVA may exceed 500 kVA.
[b]All kilovolt ampere ratings are minimum nameplate kVA for the principal winding.

Table 2—Transformer short-time thermal load capability

Transformer category[a]	Time (s)[b]	Times rated current
I	2	25.0
II	2	25.0

[a]For Category II transformers, the maximum through-fault current depends upon the transformer short-circuit impedance.
[b]Refer to IEEE Std C57.96-1999 for loading capabilities at durations longer than 2 s for Category II transformers.

Annex A

(informative)

Bibliography

[B1] IEEE 100, *The Authoritative Dictionary of IEEE Standards Terms*, Seventh Edition.